Gasification
- an Indian Perspective

Christopher Higman and R. K. Sharma
presented at "Gasification, The Gateway to a Cleaner Future"
Dresden, September 1998

Gasification – an Indian Perspective

Christopher Higman and R. K. Sharma
Lurgi India Co. Ltd.

1 Introduction

The installed power production capacity of India was on 31st March 1998 about 90 000 MW, somewhat less than that of Germany, a country with less than one tenth of India's population. With a rate of industrial growth substantially higher than that of OECD countries, there is an urgent demand for increased generating capacity - indeed a lack of availability of electric power is perceived to be a real bottleneck to future growth.

Against this background it must be seen that India has enormous reserves of coal, albeit much of it with a very high ash content. Furthermore, India is proceeding with a major expansion in petroleum refining capacity with an attendant production of petroleum coke and heavy residue. Natural gas resources are, however, limited and a significant part of this is dedicated to the fertilizer industry, the mainstay of India's "green revolution" in agriculture.

There is thus a favourable climate in India for Integrated Gasification Combined Cycle (IGCC) power generation projects using refinery residues as feedstock. This paper will review the overall energy scenario in India, in particular power demand and fuel aspects and the prospects for IGCC in it. The two attendant aspects of capital availability and power distribution will also be reviewed briefly.

2 The Energy Scenario in India

Since achievement of independence some 50 years ago, India has maintained an economy characterized by an unusually strong reliance on the state together with some of the associated features of the planned economy. This has applied particularly in the energy sector.

Demand for electricity increased at a compounded annual rate of about 9% during the period of 1981/82 -1991/92. It is expected to grow further at a compounded annual rate of 8% until 2011/12. The current overall average energy deficit of 9.5% and a peak shortage of 19% remain unserved. In terms of installed capacity, this amounts to a backlog of about 15 000 MW with average annual addition of 8 000 -10 000 MW.

Table 1 gives the target and actual capacity addition contained in the Government plans for the last four decades. There has been a continuous increase in the capacity addition, but this has not kept pace with the targets or actual demand. This has been particularly noticeable during the last decade. This trend is expected to continue for the next plan periods as well. Additional capacity of 57 000 MW is planned for IXth plan (1997-2002) and the target for Xth plan (2002-2007) is 65 000 MW.

Plan Period	Target	Actual	Gap
1951/52 -55/56	1 300	1 100	200
1956/57 -60/61	3 500	2 258	-1 242
1961/62 -65/66	7 040	4 520	-2 520
1969/70 -73/74	5 430	4 579	-851
1974/75 -78/79	9 264	10 224	960
1979/80	12 499	2 813	-9 686
1980/81- 84/85	19 666	14 226	-5 440
1985/86 -89/90	22 245	21 402	-843
1991/92	4 212	0	-4 212
1990/91	3 810	0	-3 810
1992/93	0	3 537	3 537
1993/94	4 458	4 538	80
1994/95	4 439	4 598	159
1995/96	4 818	2 123	-2 695
1996/97	2 161	1 521	-640

Table 1. Additional installed power capacity in MW: Target vs. Actual

Table 2 provides a breakdown of current installed capacity by fuel source as well as that for the additional capacity foreseen for the IXth plan (1997- 2002). Both in the past as well as for the immediate future coal-based thermal plants will play the dominant role, while hydro will also maintain a significant presence. Natural

Gas is scarce in India and though there have been discussions about importing from Bangladesh and Myanmar as well as from Central Asia, these ideas are all so fraught with political difficulties, that they cannot provide any sound basis for current planning. In the recent past a significant amount of emphasis has been placed on the use of naphtha as a fuel for power production. The origins of this phenomenon can be attributed to the recognition that a naphtha-fired gas turbine can be up and running on open cycle in about eighteen months and on closed cycle in twenty-four. An urgent necessity to bridge the power supply/demand gap led to a situation where applications were made for a total of 36 000 MW of naphtha fuelled IPP projects. Fuel linkage was granted for about 12 000 MW of projects. While a number of these projects are proceeding well, many of them were located unfavourably with regard to inward fuel transport infrastructure or outward power despatch. In the meantime it has been recognised generally that naphtha is far too expensive to find general use for power production. The result is that considerable confusion has been created.

Table 3 shows the allocations of naphtha for power production broken down by state.

Fuel	**MW**	**Addition**
	Mar '98	**IXth plan**
Coal	55 377	
Gas/Naphtha	8 777	
Total thermal	**64 154**	**39 444**
Hydro	21 895	17 411
Nuclear	2 225	880
Wind/other	900	
Total	**89 174**	**57 735**

Table 2. Planned Capacity Addition in IXth Plan by Feedstock

State	**Allotment (EQU. MW)**	**Linkage (EQU. MW)**	**Balance (EQU. MW)**	**Naphtha MMTPA**	**FO / LSWR MMTPA**	**Total MMTPA**
Punjab				0.3	0.1	0.4
Haryana	860	861	-1	0.2	0.9	1.1
Rajasthan	1415	1415	0	1.8	0.2	2.0
Uttar Pradesh	1155	1155	0	1.5	0.2	1.7
Gujarat	1230	562	668	3.7	0	3.7
Madhya Pradesh	1300	1300	0	1.3	0.7	2.0
Manlpur	40	40	0			
Andhra Pradesh	1500	1500	0	2.7	0.3	3.0
Maharastra	950	807	143	0.9	0.3	1.2
Goa	40	40	0			
Karnataka	1160	1197	-37	1.3	0.5	1.8
Tamil Nadu	800	808	-8	0.7	0.7	1.4
Pondicherry	45	45	0			
Kerala	660	727	-67	1	0.3	1.3
Total	**11155**	**10457**	**698**	**15.4**	**4.2**	**19.6**

Table 3. Naphtha / NGL allocation made by Ministry of Petroleum & Natural Gas and State-wise Allocation of Naphtha, FO, LSWR

Source- IPPAI

3 The Indian Refining Sector

The current oil refining capacity in India is approximately 62 MMTPA with additional 35 MMTPA under various stages of execution. Further nearly 45 MMTPA capacity is planned, so that capacity would be doubled over the next five years. An overview of various projects as documented in the Government planning is given in Table 4.

Currently most of the residue is blended with cutter stock for sale as heavy fuel oil. Given the demand for middle distillates, there is a clear incentive to process the residue in a fashion, which does not require degrading that middle distillate into furnace oil. Various approaches are being reviewed by different companies at present, using visbreaking, solvent deasphalting or coking technologies to recover usable lighter fractions from vacuum residue. However, no matter which technology is adopted in any particular case, further residue, be it pitch or be it coke will remain. Depending on the approach taken and the actual crude processed, it can be assumed that on completion of the IX[th] plan, somewhere between 13 and 20 MMTPA of refinery residues will be available for power production of the order of magnitude of 10 000 MW.

Company -Location	**Status 1997**	**IX Plan 1997-2002**		**X Plan 2002-2007**
	MMTPA	**MMTPA**	**Year**	**MMTPA**
BPCL- Mumbai	6,00			
BRPL- Bongaiogaon	2,35			
CRL-Cochin	6,50	3, 00	2002	
HPCL- Mumbai	5,50			
HPCL- Vizakhapatnam	4,50	3,00	1998	
IOC- Barauni	3,30	2,70	2001	
IOC -Digboi	0,65			
IOC -Guwahati	1,00			
IOC -Haldia	3,75			
IOC -Koyali, Gujarat	9,50	3,00	2001	
IOC –Panipat		6,00	1998	
		3,00	2001	
IOC –Mathura	7,50	0,50	2000	
MRL -Chennai	6,00	3,00	2002	
MRL- Nagapattinam	0,5			
MRPL- Mangalore	3,0	6,00	2001	
Central India Refinery		6,00	2001	
NRL Refinery		3,00	2000	
West Coast Refinery		6,00	2002	
East Coast Refinery				12,00
UP Refinery				7,00
Punjab Refinery				6,00
Sub Total -Public Sector Undertakings & JVs	**61,55**	**45,20**		**25,00**
Reliance -Jamnagar		15,00	2001	
Essar -Jamnagar		9,00	2001	
Ashok Leyland				2.00
Soros Refinery				6,00
Nippon Denro				9,00
Subtotal - Private Sector		**24.00**		**17,00**
Grand Total	**61.55**	**69.20**		**42,00**
Capacity at the end of Plan		**130,75**		**172,75**

Table 4. Oil Refining Capacity Planned in IXth & Xth plan

Source: IPPAI

4 Gasification in India Today

4.1 Oil Gasification

India's experience with gasification of liquid feedstocks dates back to the 1960s, when it was utilized, for production of hydrogen from naphtha for fertilizer plants. To date at least eleven plants of various capacities have been installed in the country. Details of these are given in Table 5.

Company	Locatlon	Fuel	Process	Remarks
National Fertilizers Ltd.	Nangal	LSHS	SGP	Lurgi basic design Lurgi Rectisol
National Fertilizers Ltd.	Panipat	LSHS	SGP	Lurgi basic design Lurgi Rectisol
National Fertilizers Ltd.	Bhatinda	LSHS	SGP	Lurgi basic design Lurgi Rectisol
Fertilizer Corp. of India	Sindri	LSHS	SGP	Lurgi basic design Lurgi Rectisol
Fertilizer Corp .of India	Gorakpur	LSHS	SGP	
Hindustan Fertilizers Ltd.	Haldia	LSHS	SGP	Lurgi Rectisol
Gujarat Narmada Valley	Bharuch	LSHS	Texaco	
Rastriya Chemicals & Fertilizers Ltd.	Chembur	Nat. gas	SGP	
EID Parry Limited	Chennai	LSHS	SGP	
Neyveli Lignite Corp.	Neyveli	LHSH	SGP	
Fertilizers & Chemicals Travancore Ltd.	Cochin	Naphtha	Texaco	

Table 5. Oil Gasification Units in India

Some of the older, naphtha or gas-based plants have been or are being retired to make way for modern large steam reformer plants. Nonetheless the fuel oil (low sulphur heavy stock, LSHS) based plants are giving extremely good service. For instance in the 1997-98 financial year NFL reported 123%, 111% and 110% capacity utilization at their Nangal, Bhatinda and Panipat units respectively.

Oil Gasification, thus, offers a technology, which has been proved under Indian conditions to provide a reliable source of synthesis gas in industrial service.

4.2 Coal Gasification

As with oil gasification, India has already some experience with coal gasification and has even made advances in developing an indigenous technology. Plants built in India include the following:

Company	Location	Fuel	Process	Remarks
Fertilizer Corp. of India	Talcher	Coal	K-T	Lurgi Rectisol
Fertilizer Corp. of India.	Ramagundum	Coal	K-T	Lurgi Rectisol
Indian Institute of Chemical Technology	Hyderabad	Coal	Lurgi	
Bharat Heavy Electricals Limited	Trichy	Coal	BHEL	

Table 6. Coal Gasification Units in India

The history of coal gasification in India is not as happy as that of oil gasification. This situation is intimately connected to the particular characteristics of Indian coal (see Table 7). Indian coal has the advantage of relatively low sulphur content. The problem lies in the extremely high ash content, which can often be as high as 40%, and the nature of the ash, which contains very high amounts of silica and alumina. (Typical figures from the Talcher coalfield are 60% and 30% of the ash as silica and alumina respectively. The ash deformation temperature is 1170-1240°C and the fusion temperature is above 1400°C.) This high ash content with a high melting point presents great difficulties to all slagging processes. Any gasifier operating in a slagging mode consumes more oxygen because of the heat required to keep the ash molten at the slag tap. On most coals, this disadvantage is outweighed by the advantages of high temperature operation such as elimination of all volatiles in the gas and reduced methane slip. Thus modern process developments have taken the high temperature route. The high ash content of Indian coals, however, makes modern high temperature processes extremely expensive in oxygen demand, apart from the problem of handling the large volumes of silica in an entrained flow process.

Properties		
Carbon	wt%	34 - 46
Hydrogen	wt%	32 - 35
Nitrogen	wt%	0.1 - 1.5
Sulphur	wt%	0.5 - 1.0
Oxygen	wt%	7.5 - 8.5
Moisture	wt%	6 - 8
Ash	wt%	35 - 45
Volatile matter	wt%	20 - 26
Fixed carbon	wt%	26 - 34
Gross calorific value	kJ/kg	14 500 –18 500

Table 7. Properties of Typical Indian Coal

On the other hand there is a conviction that coal gasification can assume a special significance in the Indian context. India has proven reserves of 170 billion tons of coal. When compared with reserves of oil (581 million tons) and gas (540 million tons), the reason for this conviction becomes apparent. Thus when looking at gasifying Indian coal, the tendency has to be to look at non-slagging processes. The IICT Unit at Hyderabad is a small test unit used primarily for research and coal testing purposes. The BHEL Unit at Trichy is an indigenous development, also aimed at finding a way to improve coal use in India.

It is, however necessary to recognize that since most Indian coal has a low sulphur content, relatively simple gas cleaning systems can be added to conventional combustion plants to meet the environmental requirements.

Nonetheless there are also substantial reserves of lignite in India and the possibilities are demonstrated by the fact that the first 60 MW IGCC/Cogen plant based on lignite is under serious consideration by Sanghi Industries as a captive power plant (CPP) for their cement facility at Kutch in Gujarat. It is planned to use Carbona pressurized fluid bed gasification technology supplied through IBIL Tech and licensed from IGT, Chicago. The plant is scheduled to come on stream in the year 2000.

4.3 Biomass Gasification

Biomass gasification is also receiving some attention in India. The Ministry of Non-Conventional Energy Sources (MNES) has constituted a "Round Table" with the idea of developing a national biomass gasification programme. Currently there are many small-scale atmospheric "village" gasifiers operating in the country, primarily to fuel gas-engine driven irrigation pumps, providing up to 70% diesel replacement. The development of any medium to large-scale units will depend primarily in finding a solution to the task of biomass collection. At special favourable locations such as sugar mills, there are a number of projects under review. All are however based on the assumption that a substantial government subsidy will be available.

5 Integrated Gasification Combined Cycle (IGCC) Plants

As has been seen earlier, there is a tremendous demand for new power generation capacity in India today. Apart from coal, there are few indigenous energy sources to meet this demand. Nonetheless there will be sufficient residue from Indian refineries in the next few years to produce about 10 000 MW power, or the new capacity requirement for one year. Assuming an overall realisation over the next five to ten years this could represent 10-20% of the total new generation capacity.

In this scenario there is a definite opportunity to exploit Integrated Gasification Combined Cycle (IGCC) technology. Alternative options to convert these high-sulphur, metal-containing residues to power are Circulation Fluid Bed (CFB) boilers or conventional boilers with Flue Gas Desulphurization (FGD).

In the IGCC technology the residue is gasified with oxygen to form a raw synthesis gas containing mostly hydrogen and carbon monoxide with impurities in the form of hydrogen sulphide and carbonyl sulphide. The metals are removed as an integral step in the gasification process. The gas is desulphurized in an Acid Gas Removal (AGR) unit to any desirable level prior to being used as fuel in a gas turbine. Steam generated in the gasification process and in the Heat Recovery Steam Generator (HRSG) of the gas turbine is fed to a steam turbine for further power generation. Various configurations and integration options are available and can be tailored to suit any site-specific requirements.

In addition to handling a straight visbreaker residue or asphalt, there are processes such as Lurgi's Multi-Purpose Gasification (MPG), which are able to handle other waste streams from the refinery such as tank sludges. Typical feedstocks processed by MPG are shown in Table 8. This type of process also has the flexibility to process petroleum coke, should this be the direction indicated by the refinery flowsheeting.

Component		**Actual Operating Ranges and Max. concentrations**	
		Normal Mode	**Waste Mode**
C	% wt	65- 90	90
H	%wt	9-14	14
S	% wt	6	6
Cl	% wt	2	8
LHV	MJ/kg	35-42	5-30
Toluene insolubles	% wt	6	45
Ash	% wt	3	25
Water	% wt	2	5-100
Trace components (selection only)			
Al	ppmw	600	70000
Ag	ppmw	5	10
Ba	ppmw	500	2000
Ca	ppmw	3000	170000
Cu	ppmw	200	800
Fe	ppmw	2000	40000
Hg	ppmw	10	25
Na	ppmw	1200	8000
Ni	ppmw	50	500
Pb	ppmw	200	10000
V	ppmw	10	100
Zn	ppmw	1200	10000
PCBs	ppmw	200	600
PAK	ppmw	20000	40000

Table 8. MPG-Lurgi/SVZ Multi Purpose Gasification Feedstock Flexibility (Liquids & slurries)

It is also worth noting that the gas-processing scheme can be adapted to produce a side stream of hydrogen for use in the refinery instead of having to make it out of expensive naphtha in a steam reformer. Alternatively also methanol for MTBE or ammonia for the fertilizer industry could be manufactured as additional products. Overall an IGCC using refinery bottoms can achieve an efficiency of some 45%, while reaching a degree of desulphurization well in excess of 98%.

Depending on the size of unit, overall EPC investment costs of about US$ 900 /kW installed can be achieved, competitive with alternative technologies processing similar feedstocks to similar environmental standards.

Thus in the context of an Indian refinery the integration of an IGCC power plant can provide the following advantages:

- It frees up middle distillate otherwise lost to the heavy fuel oil pool
- It allows the introduction of upgrading processes into the refinery flow scheme to produce a lighter product slate

- It allows a greater flexibility in crude processing and thus opportunities for cheaper crude procurement
- It provides a higher degree of desulphurization than other power production processes
- In contrast to other power production processes, it produces a very small amount of solid waste.
- It allows flexibility in gas processing to add products such as hydrogen or methanol at a later stage, growing with the refinery.

Against this background a number of Indian refineries have already published their intention to proceed with or consider IGCC projects. These include the projects of:

- CRL in Cochin
- HPCL (in conjunction with Andrah Pradesh SEB) in Vizakhapatnam
- MRL in Madras
- IOC in a number of their refineries, including the East Indian Refinery in Paradeep

Looking at the major parts of the IGCC unit, a discussion of existing gasification experience in India was handled in section 4 of this paper. Producing the power from Combined Cycle operation needs no reference. The concept has established itself worldwide. In India alone, more than 10% of capacity currently being installed is based on the combined cycle route. An interesting statistic: while India failed to achieve the targeted figures in every other sector (Table 9), the capacity addition on Combined Cycle has been exceed by more than 100%. Thus all the major components of an IGCC have been proven in the Indian context. What is needed now is to put this all together, as is happening already in other parts of the world.

	MoP Targets		**Actual**	
	Sets	**MW**	**Sets**	**MW**
Coal	9	2065	8	1815
Gas & CCP	12	558	20	1084
Diesel	5	100	4	80
All Thermal	**26**	**2723**	**32**	**2979**
Hydro	38	516	16	242
Total	**64**	**3239**	**48**	**3221**

Table 9. Generating Capacity Addition (Utility Sets) during 1997/98

6 Other Aspects

6.1 Capital Availability and Financing

Assuming the growth rate predicted in government planning, then the additional generation capacity required will be some 10 000 MW per annum. Assuming furthermore that with a mix of technologies the installation cost will average out at about US$ 1 000 /kW installed, then the required investment is US$ 10 billion p.a. Current estimates indicate that the public sector can only fund about US$ 3 billion of this so that the rest will have to come from IPP's, mostly with imported capital.

The biggest bottleneck for new power generation capacity, whatever the technology, is the securitization of these very large funds to be invested. Under the terms of the Electricity Act (1948), distribution of electric power is in the hands of the State Electricity Boards (SEB's), who therefore represent the customer for the IPP's. The SEB's are, however, caught in the trap of being obliged to provide subsidized power to domestic and agricultural consumers (in some states for agriculture even free of charge), while not being able to recover the subsidy from the Government (either State or Central). The resulting poor financial shape of the SEB's makes them an unattractive risk for banks and others wishing to provide funds for non- or limited recourse projects in the Indian power industry.

This problem is well recognized, both in the industry and in Government circles and is being addressed. It remains however, to be seen, whether the minimum tariff for electricity promulgated in this year's budget will really become effective in three year's time as planned.

6.2 Distribution

An additional problem for the power industry is the issue of distribution. In a country with India's geography (long distances between generation sites and large consumer centres as well as a widely dispersed distribution of small consumers) the investment requirement for transmission and distribution (T&D) approximates that of the accompanying generation capacity. The T&D arm of the industry has been notoriously underfunded for decades. This would imply that in addition to an estimated US$ 10 billion p.a. to distribute the planned new generation capacity, further funding will be needed to catch up on the backlog of neglect.

Power losses in India's T&D system amount to 23% of power produced, compared with about 6-11% in both OECD and other developing countries. The estimated break-up of these losses is shown in Table 10.

Looking at this data, it can be seen that the real problem is in the distribution system. The "non-technical" losses include a substantial component of outright theft. The causes of the high technical losses are manifold and include

- High transformation losses due to the many stages of transformation
- Use of low voltages for distribution, where high voltage would be more appropriate
- Lack of investment in adequate reactive compensation in the system
- Lack of metering to agricultural consumers

Losses	**%**
Transmission losses (400 kV, 220 kV, 132 kV and 66kV)	4.0
Distribution losses (non-technical) (33 kV, 11 kV and 400 volts)	5.0
Distribution losses (technical) (33 kV, 11 kV and 400 volts)	14.0
Total losses	**23.0**

Table 10. Losses in the Indian T&D system

This situation is part cause and part result of the poor financial health of the SEB's. What it means for the developer of any power generation project in India is that proper attention to the power evacuation study is far more critical than in those locations, where IGCC projects are currently being realized.

7 Conclusions

India has a desperate need to develop its physical infrastructure and an improved and reliable power supply has to be the foundation of any advance in this direction. In the long term the major increase in generation capacity will have to come from domestic coal supplies, probably using pithead units with conventional technology. In the medium term there is, however, considerable opportunity for a significant contribution using IGCC technology hand in hand with the expansion of the refining industry.

Gasification of heavy fuel oils is a proven technology, already established and successful in the Indian fertilizer industry. Similarly gas turbines are no stranger to the Indian power market. Thus there is a core of experience in the country already familiar with the two key technologies for an IGCC.

The bedding down of current IGCC projects in Europe and the USA is well under way. This provides good grounds for anticipating that this efficient and environmentally friendly technology will arrive in India in the foreseeable future. A significant number of realistic projects have already been identified.

The success of these projects will, however, be largely determined by parallel development in the transmission and distribution part of the industry.

References:

[1.] **Anon**, "Planning for the Indian Power Sector", Canadian Energy Research Institute and Tata Energy Research Institute, June 1995.

[2.] **H. Dhaul & J. Hossain**, "The State of Indian Power -1998", Independent Power Producers Association of India, January 1998.

[3.] **W. Liebner**, "MPG -Lurgi/SVZ Multi-Purpose Gasification, a New and Proven Technology", Tenth Refinery Technology Meet, Mumbai, February 1998.

[4.] **Anon**, "NFL clocks Rs 2,221-crore sales", Economic Times, New Delhi, 10th April, 1998

Tables